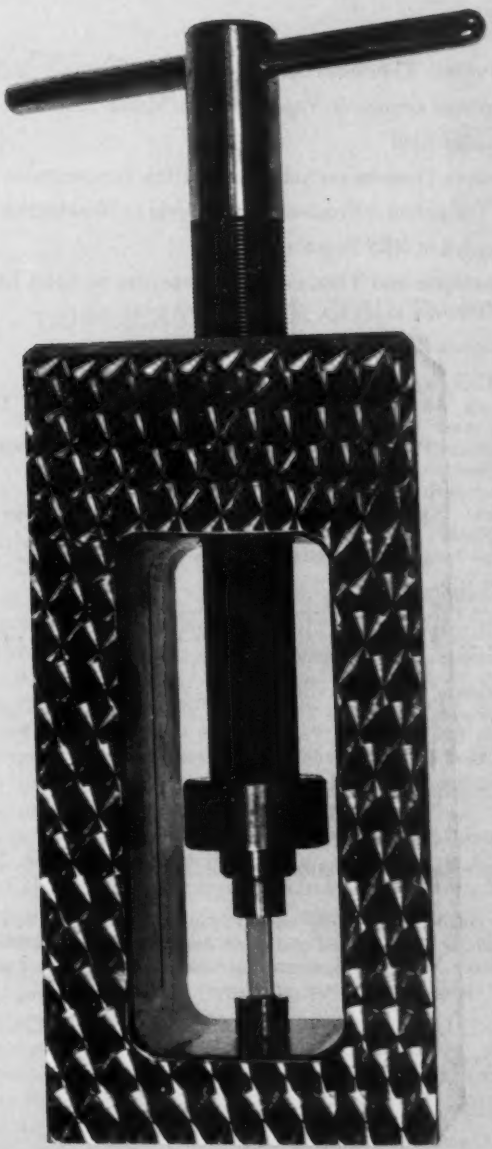
A UNITED STATES DEPARTMENT OF COMMERCE PUBLICATION

August 1970

NATIONAL BUREAU OF STANDARDS

Technical News Bulletin



UNITED STATES DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

Technical News Bulletin

AUGUST 1970 / VOL. 54, NO. 8 / ISSUED MONTHLY

U.S. DEPARTMENT OF COMMERCE
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NATIONAL BUREAU OF STANDARDS
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COVER: *This specially-made screw clamp can apply up to 10,000 bars of compressive stress to crystal and glass laser materials such as the 25-cm long, rectangular prism of ruby shown. The article on page 177 describes one study in the Bureau's research program on laser materials.*

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The National Bureau of Standards serves as a focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. For this purpose, the Bureau is organized as follows:

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CRYOGENIC FLOWMETERING AT NBS

An Example of Government-Industry Cooperation

THE NBS CRYOGENICS DIVISION, in cooperation with the Compressed Gas Association, has established a cryogenic flowmetering and research facility at Boulder, Colo. Work at this facility will help solve what may be the most significant current problem of the cryogenic industry: the accurate measurement of flowing cryogenic liquids.

In 1970, cryogenic liquids produced in the United States will have a total value of approximately $500 million, according to the ISA Ad-Hoc Committee on Cryogenic Fluid Metering. This volume will triple within the next five years in the committee's estimation. The enormity of the figure indicates that the problems related to producing tonnage quantities of liquefied gases have been practically solved. As these large quantities of cryogens flow through distribution channels from producers to consumers, it will be painfully evident that there is another problem that is not so well in hand; that of accurately metering flowing cryogenic liquids.

Flowmetering may be the most significant current problem of the cryogenic industry, for upon accurate meaurement depend cost control and billing as fluids pass from the custody of producer through vendors to consumers—all of whom commonly represent separate organizations. The problem defies easy solution, but the Bureau, the Compressed Gas Association, Inc., and the weights and measures officials of the State of California have teamed their efforts to resolve it.

Peculiar properties of cryogenic liquids preclude installing a simple meter in the line and getting a precise and accurate measurement of the fluid passing through. For one thing, the extremely low temperatures of cryogens affect the operation of meters. Another problem is the variation of density due to changes in temperature and pressure. For instance, a container of liquid nitrogen open to the atmosphere in Los Angeles would contain about one percent less mass than the same container open to the atmosphere in Boulder, Colo. Compound these problems with the bumps, jolts, improper cooldown, and overspeeding that is likely to be the lot of a meter on the average delivery truck and there is real question as to whether the meter is giving an accurate measurement.

This was a question that many people in the cryogenic industry were asking in 1967 when public hearings began on the California code for cryogenic flowmetering. To make the code workable, traceability to a flow standard is required so the state can certify that meters operate within the three percent accuracy that the code specifies (two percent underregistration and one percent overregistration).

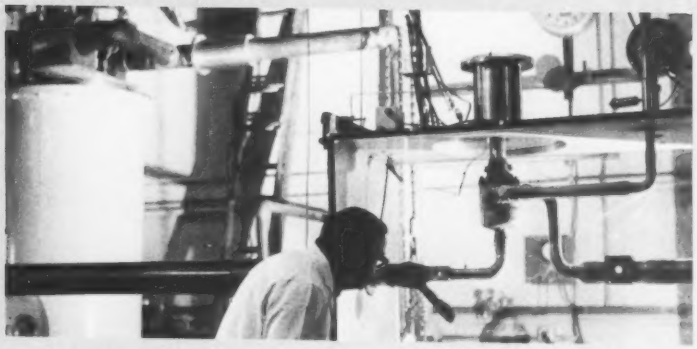
Equally as important as the mechanical accuracy of the calibration facility are some less tangible factors. The calibration and evaluation must be done by someone who is in a position to be strictly impartial, and the facility should be readily accessible to all manufacturers and users of meters. There is still another requirement. The calibration facility must have the confidence of all parties involved so that it can function effectively as an arbitrator in the event of differences of opinion between vendors, consumers, and regulatory agencies.

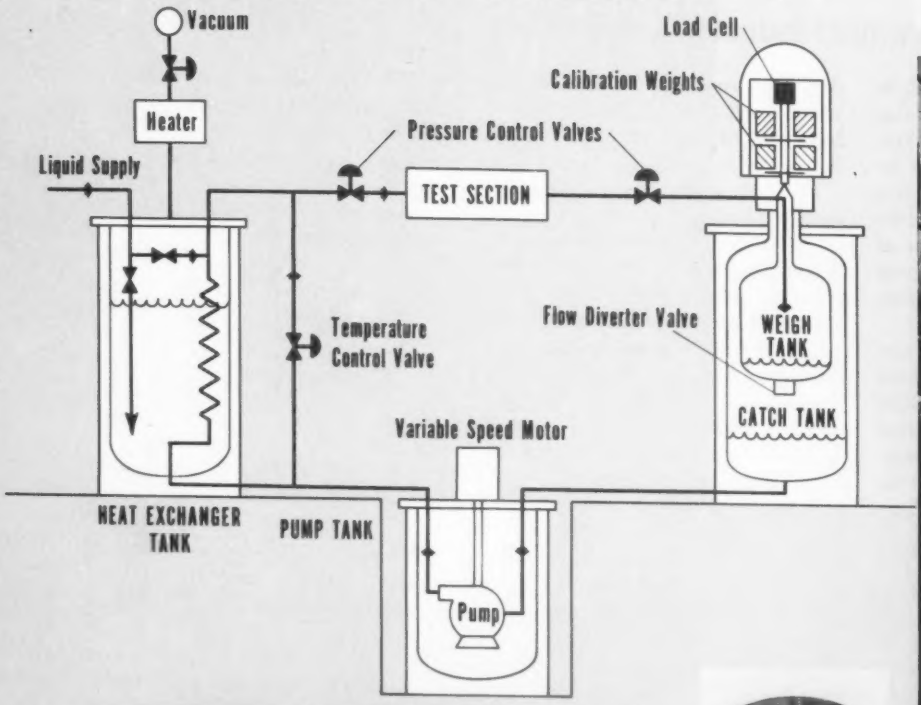
In addition to a heritage and tradition of metrological excellence and integrity, which commands worldwide respect, the Bureau was a pioneer in the cryogenic industry. In 1904 the Bureau obtained its first hydrogen liquefier and in the early 1950's it built and operated the world's first large-capacity liquid hydrogen plant, which served as a prototype for the giant industrial plants of today.

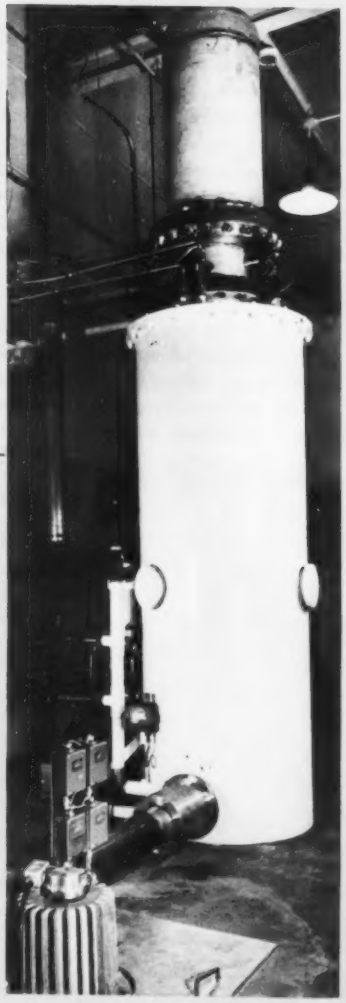
Cryogenists at NBS were sympathetic to the CGA interest for they had seen the problem developing years before. In 1963 they had drawn up a proposal for a cryogenic flow research facility but could not obtain a high enough priority to build it within the austere NBS Budget. Members of the Compressed Gas Association decided to provide funding to help establish the Bureau's flowmetering facility.

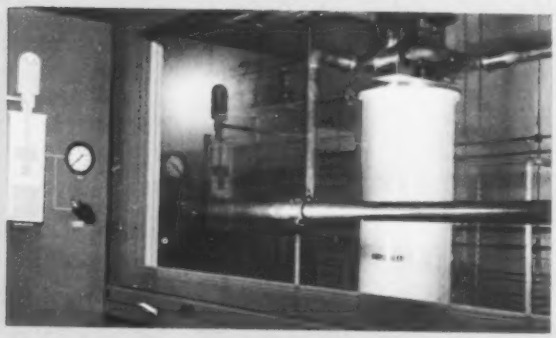
Studying and planning a flow fa-

Cryogenic Flowmetering Research Facility









cility since 1963 gave NBS scientists insight into the features their facility must have to avoid the shortcomings of calibration setups then existing. The essence of the problem was establishing a standard in a controlled environment of such integrity that meters could be compared to it with complete confidence.

Short-duration test runs that lasted only for the time it took to transfer fluid from one dewar to another was one common problem. Even with tank-car-sized dewars, the transfer time was relatively short. Wear in rotating or reciprocating parts of the meters now used in commerce cannot be predicted from short-run flow tests. Neither can relative calibration shifts be determined from short runs, and both must be known to predict when a meter will need recalibration.

In order to protect consumers, state agencies must be able to predict recalibration requirements at commercial meters, such as those in filling stations where truck drivers replenish nitrogen supplies to refrigerate their cargoes. There are now several hundred of these in the United States.

NBS solved the test-time problem by designing their facility with a closed loop system where the cryogenic liquid is continuously recirculated from the supply tank, through the pump and meter, into a catch tank, and back to the supply tank again. At the supply tank a refrigeration system removes the pump energy and heat leak from the system so thermal equilibrium can be maintained at any temperature from 63 K to 115 K. Pressure in the loop can be varied from 1 to 300 psi and flow from 20 to 200 gpm. With such flexibility, the system can duplicate the conditions of most commercial transfer for any period of time.

Constant flow rate in the NBS facility was assured by placing the pump four feet below the elevation of the rest of the system. This provides a net positive suction head at all times, even when operating at near saturation conditions.

To establish thermal equilibrium, the pump circulates the cyogenic liquid through the loop until all parts are at the same temperature before calibration is begun. The weigh tank is in series with other components of the loop, so it comes to equilibrium with the rest of the system. To begin the calibration, the diverter valve in the bottom of the weigh tank is closed and the flow from the meter begins to accumulate in the weigh tank. The calibration consists of comparing the flow indicated by the meter to the mass accumulation in the weigh tank during the time of the test. The weigh tank is suspended from a load cell with a series of weights that have been calibrated with the NBS standard of mass.

In order to be sure of the mass in the weigh tank, the action of the flow diverter valve must be absolutely positive. When it closes, it must stop the flow from the weigh tank without a trace of a leak, every time, without fail, and instantly on command. As there was no valve commercially available which could fill the requirements, the Bureau built one of its own design. It is operated by a spring bellows and normally is open. Helium pressure in the bellows closes the valve by forcing a tapered plug against double seals of Teflon rings. The spaces between the sealing rings and also the threaded mounting of the valve are purged with helium gas at a pressure slightly exceeding the head pressure of the cryogen in the system. Any possible leakage, then, will be an insignificant amount of helium gas into the system, rather than cryogenic liquid through the valve.

The weigh tank itself is made of aluminum and, located as it is within the insulated shell of the catch tank assembly, requires no additional insulation. A high ratio of active weight to tare weight is the result; this is unusual in cryogenic systems but necessary for high resolution of the active weight. The NBS system will typically have a tare weight of 150 pounds and an active weight of perhaps 700 pounds. A reverse tare/active ratio, or perhaps even worse, was not uncommon in conventional systems.

Douglas B. Mann, NBS engineer in charge of the flow-metering project, takes satisfaction in the accomplishments of the facility during the year it has been operating, but he sees more work to be done. One high-priority item Mann noted is the development of a transfer standard. State regulatory agencies will have such a standard calibrated at the NBS flow facility and then use it to check flowmeters used in commerce.

Mann also pointed out that the present NBS facility will accept nitrogen or argon but, because of material compatibility problems, will not accept oxygen which is just as important a commercial liquid. He does not see this as a serious problem however, for with the calibration data on nitrogen and argon standards, he feels they can calculate the requirements of an oxygen standard. Empirical verification will have to await funding and construction of an oxygen system.

He also sees a need in the future for higher flow capacities to calibrate standards for aerospace applications where flow rates reach thousands of gallons per minute.

"We tackled the most pressing jobs first," said Mann. "Now that we are able to furnish a flowmeter evaluation and calibration service for the meters of the most common cyrogenic liquids in commerce, we'll get to the other things as fast as we can."

In this schematic view of the NBS cryogenic flow research facility the photographic inserts detail various aspects of the installation. In the upper left a meter is being evaluated in the test section of the flowmeter research facility. The upper right photo shows the weights used with the load cell. They are calibrated with traceability to the NBS kilogram, the basic standard of mass for the United States. Below the weights is a photograph of the weighing system and catch tank assembly. Continuing clockwise, the next insert shows the cryogenic flow diverter value. It is a positive closing type designed at NBS. The lower left photo shows a part of the control panel for the system with its subcooler visible through the window.

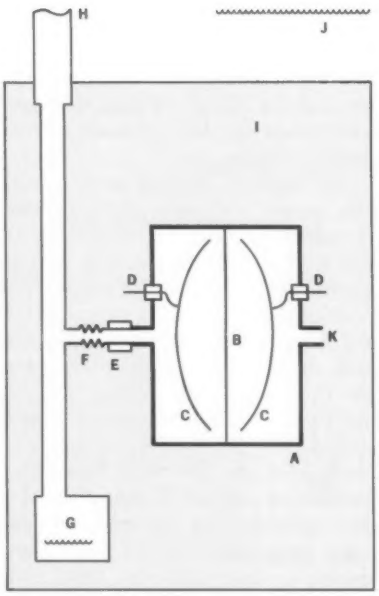
IMPROVED CRYOGENIC VAPOR PRESSURE MEASUREMENTS

RESEARCH AT THE BUREAU has shown that improved vapor pressure measurements at cryogenic temperatures are achieved by using a capacitance diaphragm manometer. In this work,[1] by R. Gonano of NBS and E. D. Adams of the University of Florida, measurements are made in situ, which eliminates uncertainties introduced by thermomolecular pressure gradients.* The increased sensitivity, greater convenience, and simplicity of this technique should result in it having wide applications in precise vapor pressure thermometry and similar work.

Thermometry in the range 0.3 K to 5.2 K is usually referred to helium vapor pressure scales (currently T_{58} for ^{4}He and T_{62} for ^{3}He). However, over a wide pressure range below about 10 torr (1 torr = 133.3 N/m^2), the vapor pressures of both ^{3}He and ^{4}He change on the order of a percent per millikelvin, so that relatively careful manometry is required for precise thermometry. For example, at about 0.3 K the ^{3}He vapor pressure is about 1.9 millitorr and changes by 0.07 mtorr (4 percent) per millikelvin; at 0.67 K it is about one torr and changes by about 10 mtorr (1 percent) per mK.

In cryogenic work, vapor pressures are necessarily generated at low temperatures while conventionally the measuring instrument is at room temperature. As a result of this temperature difference, a pressure difference is developed between the warm and cold ends of the connecting tube when the mean free path of the gas molecules is of the order of or greater than the tube radius. Traditionally this has been minimized by using tubes of large diameters and correcting for the remaining difference on the basis of tables.[2] Accuracy of this method, however, is questionable.[3] The present work was undertaken to eliminate the need for corrections by measuring the pressure in situ.

The main component of the new manometer is a commercial sensor, normally intended for use at room temperature, containing an elastic diaphragm, which divides the sensor into two symmetric chambers. One half is connected to a reference vacuum, the other to the vapor pressure under measurement. Fixed concave plates in each chamber are mounted so as to form capacitors with either side of the diaphragm. A differential pressure causes deflection of the diaphragm, which changes the ratio of the two capacitances. Hence, upon calibration, the capacitance ratio becomes a measure of pressure. Because of the symmetry, the capacitance ratio is much less sensitive to changes in dimensions (due to thermal expansion) than the value of either capacitance alone.



Schematic of the capacitance diaphragm manometer used for improved vapor pressure measurements: diaphragm sensor housing (A), diaphragm (B), capacitor plates (C), insulating feedthroughs (D), ceramic insulating tube (E), bellows (F), copper vapor pressure bulb (G), connecting tube to room temperature manometer for calibration (H), vacuum space (I), helium bath (J), and reference vacuum (K).

The sensor temperature is maintained constant at a slightly higher value than the highest temperature at which vapor pressure measurements will be made to prevent condensation in the sensor.

The ratio of the two capacitances is measured by means of a capacitance bridge operating at 5 to 10 kHz. The bridge must be of high resolution and have good linearity and stability, rather than absolute accuracy, as the whole system of sensor plus bridge can be calibrated together.

The diaphragm manometer has been calibrated at temperatures of about 3 K, 77 K, and 300 K, against an automatic mercury manometer, which is believed to be accurate to within 50 mtorr and reproducible to 20 mtorr. The relationship between capacitance and pressure is linear in the calibration region between about 8 torr and 1 torr. In view of the shape of the calibration curve and the design of the sensor, linearity is expected to be within at least 0.1 percent at and below 1 torr, which allows a precision of about 0.1 mK in vapor pressure measurement.

* This technique was conceived by Gonano and Adams at the University of Florida. Subsequent experimental work was carried out by Dr. Gonano after his move to NBS.

[1] Gonano, R., and Adams, E. D., In Situ vapor pressure measurement for low temperature thermometry, Rev. Sci. Instr. (in press).
[2] Roberts, T. R., and Sydoriak, S. G., Phys. Rev. 102, 304 (1956).
[3] McConville, G. T., Cryogenics 9, 122 (1969).

PERIODIC ACID

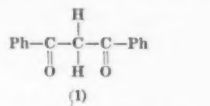
New Applications for a Chemical Reagent

In 1928 Malaprade introduced the use of periodic acid as a reagent in the cleavage of carbon-to-carbon bonds. Recent scientific investigations at the NBS Institute for Materials Research have greatly extended the usefulness of periodic acid. Alexander J. Fatiadi, who is conducting this research, reports that a most recent application of periodic acid (H_5IO_6) is the iodination of certain *beta*-diketones,[1] and conversion of certain cyclic, enolic phenylhydrazino derivatives into enolic phenylazo compounds.[2] In earlier studies with air pollutants, Dr. Fatiadi found that periodic acid is useful as an oxidant of polycyclic aromatic hydrocarbons.[3] Also, free radicals stable to 485 ± 15 °C have been obtained by treatment of the hydrocarbon azulene with periodic acid,[4] suggesting a possible use for this highly stable radical as a reference material.

As an Iodinant

As an iodination reagent, the use of periodic acid is novel and offers the organic chemist a new way of iodinating some of the *beta*-diketones. In the NBS work, periodic acid was found to iodinate the *alpha*-methylene group of *beta*-diketones, including 1,3-diphenyl-1,3-propanedione, 2,4-pentanedione, 2,4-hexanedione, and hexafluoro-2,4-pentanedione. However, when sodium metaperiodate ($NaIO_4$) was used instead of periodic acid, iodination of the methylene group was not observed. Other iodinating reagents as well (for example, *N*-iodosuccinimide) failed to iodinate the above mentioned *beta*-diketones.

Progress of the formation of the iodo compounds was monitored by nuclear magnetic resonance and electron-spin resonance techniques. As no radical participation was detectable by e.s.r. monitoring, an ionic character of the iodination process was indicated. Iodination of 1,3-diphenyl-1,3-propanedione (1) is seen as involving addition of the iodonium ion (I^+) to the double bond of (1) as an enol, to give the intermediate (2). An alternative reaction path is that the iodination process involves the addition of a molecule of hypoiodous acid, or its anion (IO^-), to give intermediate (3) that, with subsequent elimination of a molecule of water, gives as the product an *alpha*-iodo derivative of (1).



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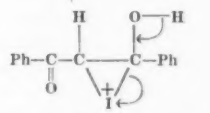

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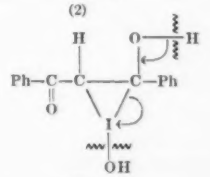


(3)

Oxidant of Hydrocarbons

Earlier studies by Dr. Fatiadi proved periodic acid to be a useful oxidant of polycyclic, aromatic compounds—common components of polluted air. In this work, supported by the Public Health Service of the U.S. Department of Health, Education, and Welfare, these aromatic hydrocarbons were subjected to laboratory-simulated conditions of atmospheric exposure. It was found that many of the products that result from natural exposure of the pollutant hydrocarbons (to air, warmth, and ultraviolet radiation, and contact with particulates) could be obtained in the laboratory by treating these hydrocarbons with periodic acid. The formation of the products of this oxidation process revealed a unique, twofold behavior of periodic acid toward polycyclic, aromatic hydrocarbons: it can either produce coupling products through a radical intermediate, or quinone products by a two-equivalent oxidation.

Treatment of Azulene

Study of the applications of periodic acid was extended to the oxidation of nonbenzenoid "aromatic" hydrocarbons. Treatment of azulene with periodic acid resulted in a solid free radical whose strong paramagnetism is remarkably stable to air and heat. Although the initial protonation of azulene with periodic acid would be expected to give a monomer cation, the isolated product is polymeric, as evidenced by its nonvolatility, thermal stability, resistance to fusion with potassium hydroxide, and visible and infrared spectra. The excellent resistance of this radical to thermal decomposition is shown by the fact that heating of a sample at 485 °C for 15 minutes (evolution of iodine) left a residue that was still paramagnetic.

[1] For further details, see Fatiadi, A. J., Novel iodination of the α-methylene group in 1,3-diphenylpropane-1,3-dione and related β-diketones with periodic acid, Chem. Commun. **1970**, 11.

[2] Fatiadi, A. J., Conversion of certain phenylhydrazino derivatives into phenylazo compounds with periodic acid, J. Org. Chem. **30**, 831 (1970).

[3] Fatiadi, A. J., Periodic acid, a novel oxidant of polycyclic, aromatic hydrocarbons, Chem. Commun. **1967**, 1087; J. Res. Nat. Bur. Stand. **72A** (Phys. and Chem.), No. 4, 341–350 (July–Aug. 1968).

[4] Fatiadi, A. J., Stable radicals obtained by treatment of azulene with periodic acid and other oxidants, Chem. Commun. **1968**, 456.

PRESSURE TRANSDUCERS SUBJECTED TO HIGH TEMPERATURES

Randolph Williams connects a pressure line to a chamber in which pressure transducers can be tested under varied temperature and pressure conditions. High accuracy in setting parameters results from use of the dead-weight piston gage (lower right) for pressure and the potentiometer (left foreground) and voltage divider for voltage measurements.

TESTS ON A GROUP OF STRAIN GAGE PRESSURE TRANSDUCERS at the NBS Institute for Applied Technology disclose that response may be altered by high temperatures. The devices had been sent to the Bureau to determine if their performance was affected by exposure to temperatures within their service range. The tests performed by Randolph Williams show that sustained high temperatures can cause changes in instrument sensitivity, zero point, and linearity that may exceed the limits specified by the manufacturer.[1] Some changes were found to be temporary and others irreversible. There was considerable individual variation; instruments of the same model differed sufficiently to establish the need for individual testing before being used for optimum results.

Pressure Transducers

Strain-gage pressure transducers are not only essential to aeronautical and space research scientists, who make many pressure measurements at high temperatures, but assume ever increasing importance in such areas as industrial process control, power generation, and bio-medicine. Many of the users are Government agencies, several of which banded together in 1951 to establish the InterAgency Transducer Project to employ the Bureau's expertise in developing methods for the evaluation of transducer performance.[2] The transducers used in the present study had been sent to the Bureau under this program, which now is supported by the Naval Air Systems Command.

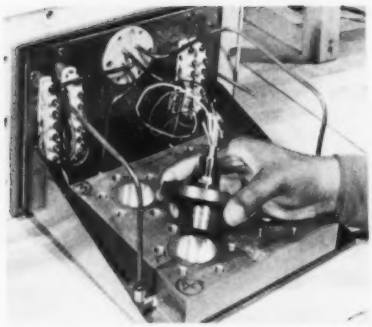
The pressure transducers supplying the data for this study consisted of six conventional transducers of the metallic strain gage type, one high-temperature (343 °C) metallic strain gage type, and three semiconductor types. The conventional metallic transducers, all intended to operate to an upper limit of about 121 °C, included three identical devices using unbonded wire strain gages, a bonded wire type, and two different bonded foil strain gage types. The semiconductor group consisted of two different transducers with strain gages bonded to the diaphragms and one transducer with the strain gage connected to the diaphragm by linkage.

Apparatus and Procedure

The test apparatus accommodated four transducers in a chamber thermostatted to within ±½ °C of the temperature desired, which was verified by a thermocouple probe. The transducers under test were subjected to pressures up to 50 psi, known with an uncertainty of less than 0.05 percent by measurement with a dead-weight piston gage. Transducer excitation voltages came from power supplies specified by their manufacturer to drift less than 0.2 percent during any 8-hour period following warm-up. These voltages were checked by means of a potentiometer and voltage divider having a combined error of less than ±0.02 percent. A potentiometer was also used to measure transducer outputs.

All of the transducer specimens were tested for eight weeks under continuously applied excitation voltage. Each test run started with three successive calibrations of the three or four specimens at laboratory ambient temperature to appraise short-term repeatability. The temperature characteristics of the specimens were then determined by statically calibrating them at 11 pressures for several temperature levels. Maximum temperatures used were 93 °C for one group and 117 °C for the second and third groups of specimens, both within the ranges specified for all of the transducers.

Following this preliminary test, the group of transducers was put through a regimen of calibrations at laboratory ambient and at elevated temperatures, 91 °C and 107 °C. It consisted, in brief, of elevating the specimens to the high temperature and calibrating them daily for 5 days, storing them at the ambient over the weekend, and repeating this cycling for a total of five weeks. This was followed by three weeks at ambient temperature, during the first of which the specimens were calibrated daily. Finally, during a day of the last week, the



Pressure transducers for performance-testing at varied temperatures are mounted on "plugs" that fit into pressure wells. Four transducers can be mounted on the tray; copper lines permit pressurizing each of the four positions separately when desired.

transducers were subjected to three successive calibrations.

Findings

The ten strain gage pressure transducers tested, though few in number, provided data leading to several conclusions. The elevated temperature period of the experiment produced shifts in sensitivity that ranged from −0.7 to +0.3 percent, and shifts of zero output from −2.5 to +4.5 percent of full scale. Permanent effects remaining after the storage at ambient were small for sensitivity (−0.4 to +0.4 percent), but substantial for zero pressure output (ranging from −3.0 to +4.5 percent of full scale).

All types of transducers tested underwent some changes with storage at elevated temperature. One of the most changed was a wire strain gage type intended for use at high temperatures—up to 650 °F (about 343 °C).

Most interesting, the three identical bonded wire transducers underwent changes in value of zero-pressure output following high-temperature storage with a maximum spread of 2 percent of full scale output. The variability of even identical specimens and the fact that most of the observed changes occurred early in the test period may prompt users requiring highly stable zero-pressure output to test and possibly "bake in" strain gage pressure transducers before use.

[1] For further details, see Williams, R., **The Effects of Extended High-Temperature Storage on the Performance Characteristics of Several Strain Gage Pressure Transducers**, Nat. Bur. Stand. (U.S.), Tech. Note 497, 18 pages (Oct. 1969), available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 for 30 cents. Order by SD Catalog Number C13.46:497.

[2] **Transducer evaluation, more economical and meaningful measurements**, Nat. Bur. Stand. (U.S.), Tech. News Bull. **53**, 62–63 (Mar. 1969); available from the Superintendent of Documents for 30 cents. Order by SD Catalog Number C13.13:53/3.

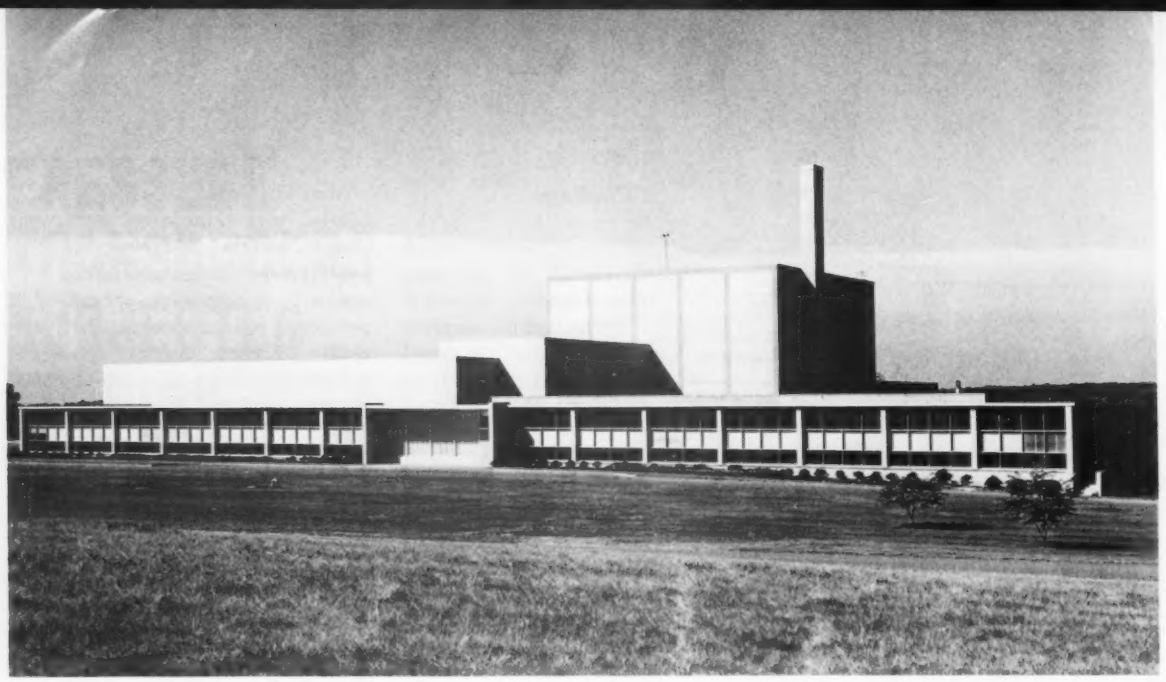
5th TEMPERATURE SYMPOSIUM TO BE HELD IN WASHINGTON

The 5th Symposium on Temperature, Its Measurement and Control in Science and Industry, will be held at the Sheraton Park Hotel, Washington, D.C., from June 21 to June 24, 1971. Sponsored by the American Institute of Physics, the Instrument Society of America, and the National Bureau of Standards, the Symposium is expected to attract over 1000 experts on thermometry from around the world to review new techniques developed in the last decade and to cover the present state of the art.

Prospective authors are invited to submit abstracts for consideration to the Program Chairman: Dr. H. H. Plumb, 5th Temperature Symposium, Room B222, Physics Building, National Bureau of Standards, Washington, D.C. 20234. Final deadline for abstracts is January 4, 1971; full manuscripts must be received no later than May 1, 1971.

Because temperature plays an important role in science and in a wide range of processes, both industrial and biological, constant efforts are being made to measure and control temperature with greater accuracy and effectiveness. The Symposium will provide researchers an opportunity to present the results of their latest investigations in these areas. Technological areas of thermometry to be discussed at the Symposium include: temperature scales; radiation pyrometry; resistance thermometry; thermocouples; magnetic and quantum electronic thermometry; potentiometers and bridges; automated measurements; geophysical, space, and biological thermometry; special thermometric devices; and temperature controls. The Proceedings of the Symposium will be published.

For further information concerning the conference, as it becomes available, write to: Vincent J. Giardina, Instrument Society of America, 400 Stanwix Street, Pittsburgh, Pa. 15222.



RESEARCH AT NBS REACTOR

DURING THE PAST YEAR, the high-flux (1.7×10^{14} n/cm^2 · s) nuclear reactor at NBS has been used in research of the structure and dynamics of materials, activation analysis of material impurities, radiation effects, and nuclear physics. The NBS Center for Radiation Research operates this large, area-unique installation as a National Facility, encouraging scientists from other Government laboratories, universities, and industry to participate in the various research areas in which the Reactor is useful.

The NBS Reactor (NBSR) achieved criticality in December 1967. Now, the NBSR having undergone its first regular fuel replenishment, is an appropriate time to describe some of the instrumentation and initial projects involving the use of the NBSR.

Instrumentation

Instruments presently in operation on the NBSR include four neutron diffractometers for crystal and liquid structure work, and a crystal time-of-flight instrument for neutron inelastic scattering. Also being developed are a triple-axis spectrometer for crystal dynamic studies, and a high resolution cold neutron facility for studying the dynamics of solids, liquids, and molecules. Irradiation thimbles, a thermal column, and a thermal beam facility are also being operated for neutron irradiation necessary in activation analysis, radiation damage studies, and nuclear research.

The four neutron scattering diffractometers and an x-ray diffractometer are controlled by a single computer [1] on a live time-shared basis. This provides a highly efficient means of coordinating many experiments simultaneously. In addition, the computer enables operations to be repeated as many times as necessary, leaving the scientist free to study the results. Although the computer remotely controls all the experimental routines, individual computer input/output stations are established at each experiment and at other Bureau locations. These enable the scientists to control experimental operations locally as well as through preprogrammed computer instructions.

The NBSR computer system was designed to fulfill three experimental requirements. First, it can collect and reduce any data an experiment may produce. Second, it can run each experiment independently of any others. Third, it uses the well-known FORTRAN computer language to enable good man-machine communications, incorporating any type of input/output mechanism.

NBS Programs

A number of active experimental programs are now in progress. The Reactor Radiation Division's neutron solid-state physics group is engaged in

research on the structure, dynamics, and interatomic forces in inorganic crystals, hydrogen-bonded materials, and organic solids including plastic crystals. Hydrogen-bonded bihalide salts, phosphonium halides, neopentane, and hexamethylbenzene are some of the materials being studied using neutron diffraction, inelastic scattering, and Raman and infrared spectroscopy.

Fission physics research, including studies of ternary fission in ^{235}U and measurements of the kinetic energy distribution of ^{239}Pu α-accompanied fission is being carried out by Center researchers. Another group is developing a technique for precise neutron flux measurements using small glass beads containing sufficient ^{10}B and Co so that virtually all the thermal neutrons striking the bead are absorbed for activation and the subsequent determination of the amount of radiation absorbed.

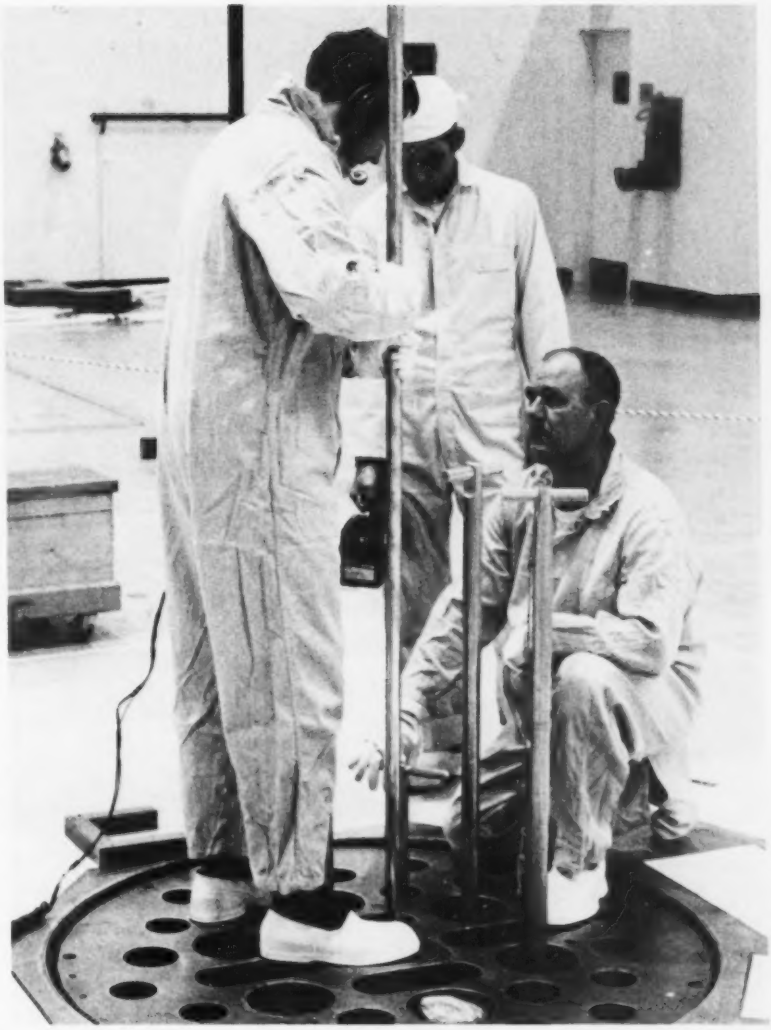
In addition, the Reactor facilities are being used either cooperatively or independently by other NBS groups. Largest among these groups is the Analytical Chemistry Division, which has an extensive effort in activation analysis to determine the types and quantities of trace elements present in materials.

From the Inorganic Materials Division, crystallographers are studying the structure and hydrogen bonding forces in complex organic crystals, while solid-state physicists analyze the dynamics and structure of solid and liquid alloys and defects in metals.

Dental researchers and polymer crystal physicists from the Polymers Division are using the Reactor to look at inorganic crystal structures and the dynamics and phase transitions of long-chain hydrocarbons, such as nonadecane.

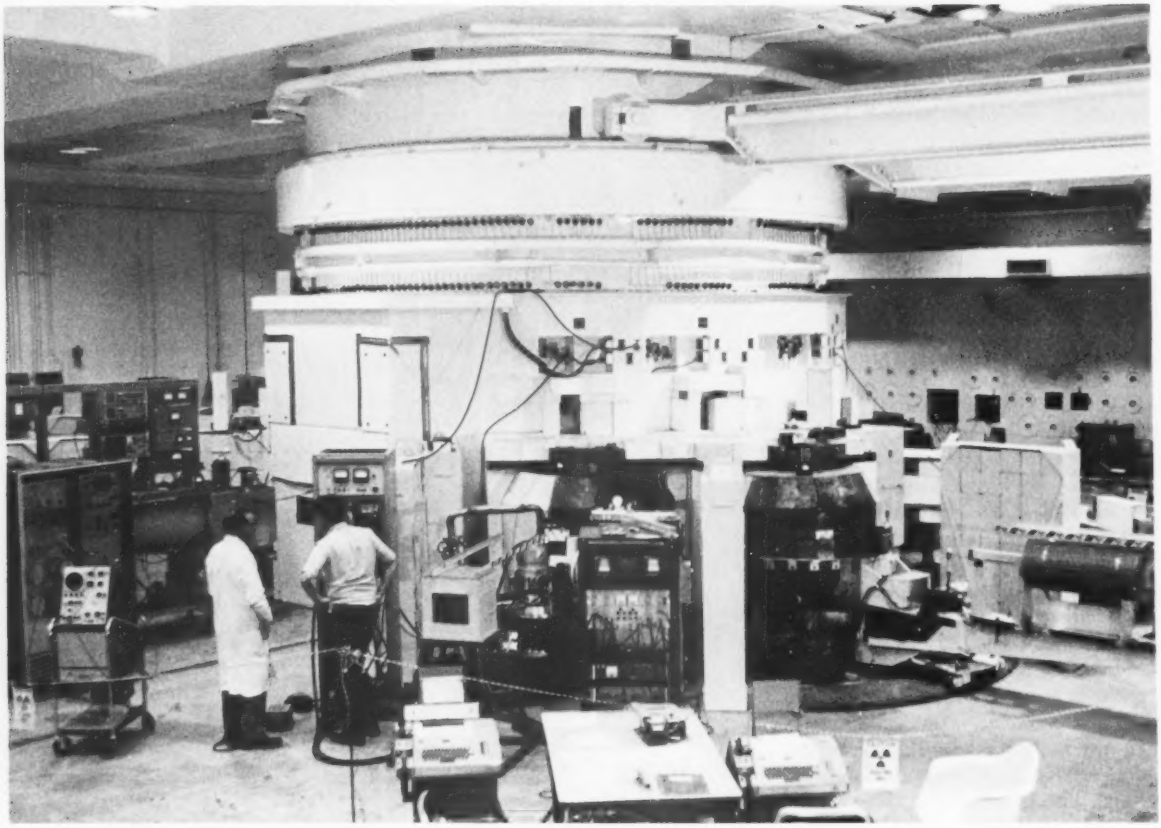
Interagency Work

Reactor physicists are participating in a cooperative program to compare activity measurements made by several laboratories on identical sources irradiated in the NBS Reactor under uniform conditions. A Los Alamos physicist has joined with NBS researchers in setting up and calibrating a ^{235}U fission neutron source (about 5×10^{10} fission neutrons per second) in the NBS Reactor's thermal column. In late April two types of monitors were activated with the NBSR fission neutron source, and then sent to several laboratories where their specific activities will be determined. The ASTM will collect the results and determine the variations and inconsistencies present in today's techniques for measuring neutron dose in reactor structural materials.



During refueling operations, Richard D. Beasley, Jr. (left) and Arthur L. Chapman (right) use long handled tools to move a fuel element under the top shielding plug, while Claude A. Rowe checks for possible radiation contamination with a portable geiger counter.

The Naval Ordnance Laboratory (NOL) and the Naval Research Laboratory (NRL) are making extensive use of the NBSR. NOL researchers are using neutron diffraction techniques to study a wide range of magnetic materials, including GdN, EuSe, $RbNiF_3$, and $PrSn_3$. A type of magnetic interaction exists between these materials and a neutron because of the neutron's magnetic moment. These



Some experimental equipment used with the NBS Reactor include a neutron time-of-flight tube (far left) stationed before the port of a large, square thermal column, and two neutron diffractometers (center and far right) used for material structure studies.

studies will help elucidate the fundamental interactions between the atoms that contribute to the magnetic properties of these materials. NRL scientists are using the NBSR to obtain extended data to determine the structure of amorphous silicon dioxide (SiO_2)—the basic constituent of many glasses. These studies will use the neutron diffraction technique to explain previous discrepancies in SiO_2 structure data. Future studies are planned to determine the structure of germanium dioxide glasses.

Starting in July 1970, an extensive neutron activation analysis program will be initiated involving five other Government agencies—the Post Office Department, Internal Revenue Service, U.S. Geological Survey, Federal Bureau of Investigation, and Food and Drug Administration. Much of this effort will be directed towards supporting forensic activities.

University Collaboration

Center staff at the Reactor are also involved in cooperative research with university scientists. Scientists from the NBSR and the Center of Materials Research at the University of Maryland are investigating the dynamics of hydrogen-bonded crystals using both the optical facilities at the University and the neutron scattering equipment at the NBSR. A student from American University is studying the structure of liquid aluminum by neutron diffraction: cooperative research studies on solids and liquids with other interested university groups are in the planning stages.

In the area of nuclear physics, Brookhaven and Harvard scientists are joining with NBS in the search for a weak parity-violating nuclear-nucleon interaction in the reactions $^{113}Cd(n,\gamma)^{114}Cd$ and $D(n,\gamma)T$; while an American University student aids in the search for a double photon emission in (n,p) capture; and a student from the University of Maryland has recently completed measurements of the neutron spectra in the NBS Reactor core.

[1] Diffractometer Control System: A System for Easy Man-Machine Communication, NBS Motion Picture, 16mm color/sound; 15 min.; 1969. Available on loan from NBS.

PIEZO-OPTIC AND THERMO-OPTIC PROPERTIES OF SOLID LASER MATERIALS

Ruby and Neodymium-Doped Glasses

In Glass and Crystal Lasers a distorted wavefront of light is often created by heat-induced changes in the material's refractive index. The thermal gradient produced by the heat of a laser's flash lamp not only changes the refractive index directly, but also creates internal stresses that further affect the index. In order to compensate for these distortions, the piezo-optic and thermo-optic constants, which define a material's optical behavior under stress and temperature, must be known.* In work partially supported by the Advanced Research Projects Agency of the Department of Defense, R. Waxler, G. Cleek, E. Farabaugh, and A. Feldman of the NBS Institute for Materials Research determined the piezo-optic and thermo-optic constants for six important laser materials—ruby and five compositions of neodymium-doped glass.[1]

Piezo-Optic Study

The NBS researchers determined the piezo-optic constants (and the elasto-optic constants) from refractive index measurements obtained while stressing a rectangular prism specimen. In a study such as this, where it is important that the distribution of stress be uniform, the specimens were stressed both hydrostatically and by uniaxial loading. With the hydrostatic method, the specimen is immersed in a mineral oil and pressures up to 1000 bars are generated by compressing the oil. With the uniaxial loading method, uniform pressures up to 10 000 bars are attained with a specially-made screw clamp.

In stressing a specimen, an optical interference method (shifts in interference fringes) is used to determine the absolute change in optical path length and the change in optical path difference of a light beam traversing the specimen. By measuring the fringe shifts, and taking into account the changes in thickness of the specimen, changes in the refractive index are calculated. Then, by choosing different crystallographic directions for stressing and different directions for light beam propagation, a sufficient number of simultaneous equations are obtained to evaluate all of the piezo-optic constants. For ruby, the constants are either negative or only slightly positive; for the glasses, the values are, as expected, positive.

Thermo-Optic Study

The thermo-optic data are determined interferometrically from the change in refractive index with temperature. A specimen, in the form of a plate with flat, polished faces, is used to determine the change in optical path length. A second specimen, in the form of a small tripod, is used to measure thermal expansion. Then, from a knowledge of the thermal expansion and a measurement of the shift in fringes with change in temperature, the thermo-optic data can be obtained.

The change in refractive index with temperature was determined for ruby from 0 to 600 °C. The data show an increase in the refractive index for both the ordinary and extraordinary rays. The refractive index-temperature data obtained for the five neodymium-doped laser glasses from 0 to 300 °C show both positive and negative values and small changes with temperature.

In both studies, a viewing apparatus equipped with camera and fast-process film made it possible to continuously record the interference fringes and to determine all the index changes in the specimens. The specimens had been ground and polished until the localized Fizeau-type fringes could be observed between opposite faces.

These piezo-optic and thermo-optic studies had their inception in work at NBS on the change in polarizability with interatomic distance. Later it became evident that the data would have many applications not only in laser technology, but in other areas of optical design as well.

*The combined facilities and expertise of the glass section, the solid state physics section, and the crystallography section within the Bureau enable complete photoelastic measurements to be made on single crystals and glasses from 1 to 1000 bars. The change in refractive index with temperature for these materials can be determined over a temperature range from −196 to 1000 °C. Dispersion data can be obtained from the near infra-red through the visible region of the spectrum.

[1] Waxler, R. M., and Farabaugh, E. N., Photoelastic constants of ruby, J. Res. Nat. Bur. Stand. (U.S.), **74A** (Phys. & Chem.), No. 2, 215–220 (Mar.–Apr. 1970).

Occupant Restraint Program

Automotive Safety Goal of Research for DOT

BUREAU ENGINEERS are conducting a vigorous program of research on automobile occupant restraint systems, one of three NBS programs[1] supported by the Department of Transportation. Directed by Richard W. Armstrong of the Bureau's Office of Vehicle Systems Research, the program's results will be used by the DOT National Highway Safety Bureau in updating Federal automotive standards. This research should greatly influence automotive safety during the 1970's.

Occupant Restraints

Seatbelts, one form of occupant restraint, have a history dating from the early days of automobiles. Around the turn of the century they were sometimes used to keep motorists from being jolted out of their horseless carriages by the rough roads. Those who lived dangerously also used the seatbelt; in 1910 U.S. Army Plane No. 1 was equipped with one. In 1922 Barney Oldfield introduced it to auto racing, where its use has since become mandatory.

As road surfaces improved, the motoring public no longer felt the need of restraints and seatbelts disappeared from the family car. The trend was reversed in 1949, when one auto manufacturer offered seatbelts as a factory installed accessory.

Continuing interest in seatbelts during the 1950's was evidenced by a seatbelt study by the U.S. Air Force and by specification of seatbelt performance requirements by the Society of Automotive Engineers. Public acceptance was still lacking, however. A study of the highway deaths during the 1960 Fourth of July weekend showed that none of the 442 motorists killed had been wearing safety belts. Safety authorities estimate that 15 percent of these motorists would have survived had they been wearing seatbelts and 90 percent would have survived if they had been wearing lap belts and upper torso restraints.

From 1961 on the story of seatbelts takes a more rapid pace. All 1962 cars manufactured in the United States had seatbelt anchorages for the front seats, the American Seat Belt Council approved some models of seatbelts in that year, and seatbelts appeared as standard equipment on the front seats of all 1964 cars and on both front and rear seats in 1965.

During the 1960's many states enacted seatbelt legislation and in 1966 President Lyndon Johnson signed the National Traffic and Motor Vehicle Safety Act. Final impetus was provided for making and enforcing occupant restraint performance standards when the Department of Transportation was formed in 1967.

Seatbelt Component Testing

Early NBS occupant restraint research was devoted to testing seatbelts only, under Federal legislation effective in December 1965.[2] Webbing and buckles were tested for various characteristics separately and the assembled seatbelt with attachment hardware was tested for strength. The specifications for webbing resulting from this work included requirements for resistance to abrasion, degradation by light, mildew damage, color change, and color transfer to clothing.

An obvious test is for webbing strength. This is measured by a ten-

In this "family," each "person" will ride on a sled that subjects "him" to the same forces as would a crashing car. The subjects range from a 217-pound "man" to a 105-pound "woman" and their "children" weighing 31 and 49 pounds.

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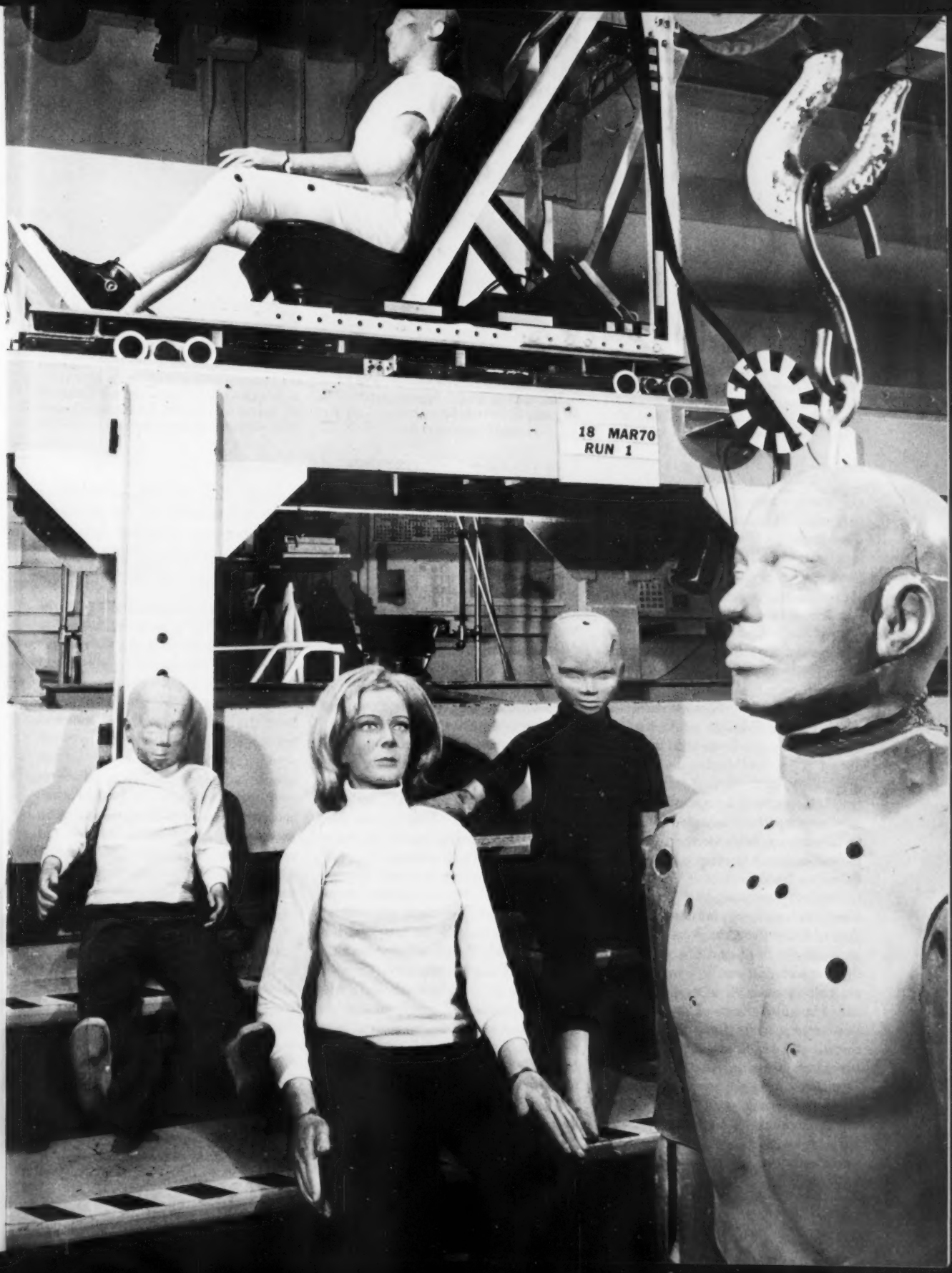


Johnathan Haines hands an upper torso strap to Mattie Johnson, who is seated in a device that can be adjusted to simulate the seat and occupant restraint geometry of any automobile.

Dorian Sanders positions webbing in a tensile test machine to determine at what tension the belt breaks. Seatbelt webbing that has been subjected to controlled stress is tested in this way.

Tilt-lock characteristics of a seatbelt buckle are determined by Alfred Castle, Jr. Lapbelts should be easily adjusted when the buckle is tilted 90°, but should clamp the webbing when tilted 30° to it.

sile test machine that is instrumented to yield data on stretching force and displacement. Webbing is tested intact and after it has been subjected to controlled environmental conditioning simulating usage. For example, a test is conducted to determine abrasion of the webbing at the buckle due to repeated adjustment, which can reduce seatbelt strength to dangerous levels in only six months if webbing and buckle are not properly designed. The webbing strength is determined in the laboratory by tensile test after abrasion preconditioning by a device designed at NBS. A new standard resulting from the findings of the abrasion tests has been adopted by industry, resulting in improved webbing and adjustment devices that are free from this problem.

Seatbelt webbing of manmade fibers such as nylon may be seriously degraded by the ultraviolet radiation in sunlight. Specifications limiting this degradation are now found in all seatbelt standards. Degradation is tested by subjecting webbing to radiation from a carbon arc for a certain duration and then measuring webbing breaking strength. The degradation resulting can cause webbing strength to drop as much as 60 percent. Lack of agreement among measurements led to research that identified the radiation source as an inadequately controlled parameter. The Bureau is now preparing a device that will enable users around the country to compare and standardize arc intensities of the radiation device.

Early NBS tests of webbing and hardware were performed at the temperature and humidity encountered in the laboratory. The Bureau soon found sufficient differences in seatbelt performance with variation of these conditions to indicate a need for the tests to simulate temperatures and humidities spanning the range of those encountered in North America.

Humidity was found to accelerate abrasion degradation and thus lower webbing strength. The Bureau devised an inexpensive humidity chamber and mechanical abrader to measure this and more recently has installed a walk-in environmental chamber for a variety of tests. Its interior can be maintained at temperatures from 0 to 60 °C and relative humidities from 5 to 95 percent.

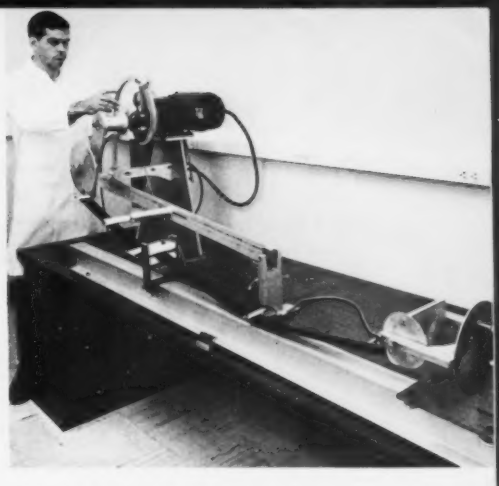
Corrosion of metal seatbelt parts—buckles, retractors, and attachment hardware—has been recognized as a problem. Corrosion takes place at a high rate in areas where chemicals are used to combat snow, since passengers track the chemical solutions inside and they are absorbed by the car's floor matting. Both salt and moisture are present inside the car in concentrations that continuously expose hardware to corrosion. The Bureau is evaluating these problems and establishing performance criteria for seatbelt hardware by using a salt spray test chamber.

Mechanical characteristics of the buckle that have been evaluated to develop specifications for DOT are: the length adjustment system (locking of which should occur when the belt is tilted not less than 30 degrees from the buckle's plane), resistance to mechanical failure, ability to withstand repeated latch-and-release operations, the upper limit of force required to release the buckle when under tension (as when holding an occupant of an upside-down car), and crush resistance (simulating being caught in a door or in the hinge of a seat).

Seatbelt retractors, which function to store webbing and in addition may adjust length or automatically lock up on impact, are subjected to the same humidity, temperature, and corrosion tests as other hardware. In addition, they are exposed to endurance cycling tests both in and out of a dust chamber to determine wear on bearings and the possibility of the mechanism being clogged by dirt. Inertial locking retractors, which use an inertia latch to prevent webbing release during a crash, were studied and tests

How well seatbelt retractors perform in a sandy or dusty area is found by operating them in this dust chamber. Claude Melton shows how the three retractors are actuated. Salt spray chamber is in background.

An environmental chamber permits seatbelt assemblies and components to be stressed at temperatures from 0 to 60 °C and relative humidities from 5 to 95 percent. Claude Melton adjusts webbing abrader.



How reliably a seatbelt's inertial locking device grips in response to a rapid withdrawal is tested by this machine. John Griffith adjusts the mechanism that yanks on the belt every fifth stroke.

developed to determine if they lock up as required at accelerations greater than 0.5 *g*.

Dynamic Tests of Restraint Systems

Bureau engineers believe that the restraint system should be tested and specified as a system, which would include the lap belt assembly, torso restraints, the car seat, and anchorages. They feel, in addition, that the test should be a dynamic one simulating actual crashes—"testing it like it's used."

The sled apparatus designed and installed at the Bureau demonstrates that dynamic testing does not require expensive sled installations. The high cost of other sleds results partly from the use of a 3500- to 4000-pound sled, which requires large energy sources and braking systems to accelerate and decelerate it rapidly.

The NBS dynamic test equipment provides a crash impulse by rapidly snatching the sled backwards, which has the same effect as stopping a forward-moving sled or crashing an automobile. This is accomplished when a spinning flywheel engages a cam that reels in a long strap attached to the sled. The NBS sled is unique in that the sled inertia, normally obtained by a massive sled giving the desired dummy-to-sled mass ratio, is obtained from the rotating flywheel, which is coupled to the sled only during the pulse. The flywheel is disengaged after the short crash pulse, so that only the 400-pound sled and dummy need be brought to a gradual stop by a cable and disk brake. This design feature reduces the cost of an installation from about $\$\frac{1}{2}$ million to perhaps one-tenth of that figure.

The sled is being used with dummies instead of people, taking advantage of the people-dummy relationships found in experimentation for NBS on the Daisy Decelerator at Holloman Air Force Base. The difference in performance of human subjects and anthropomorphic dummies has already been noted at the Bureau.[3] The structure and compliance of dummies may approach characteristics of entirely passive humans, but no dummy can brace his feet against the floor as impact approaches, nor set other muscles to minimize the consequences.

The Bureau has an extensive array of dummies—from a slight, 5th-percentile woman (only 5 percent of the female population is smaller) to a bulky, 95th-percentile man. The Bureau shares its findings from using dummies with the manufacturers of the dummies, none of which has a sled of its own.

The Bureau is giving attention to the problem of restraint systems for infants and children, as well. Children cannot be considered just "small adults"; restraining them is difficult because they don't have as defined and strong a bone structure. The kinematics of their bodies is entirely different from that of adults, partly because their heads are large compared to their bodies and their legs relatively short. The Bureau has two child dummies, representing 3-year-old and 6-year-old children, that it is using in tests on the sled.

Seat and Attachment Geometry

Early studies of dummy performance in automobile restraint systems disclosed that on sudden crashes they slouched down in the seat, allowing the hips to ride down under the lap belt. When NBS analyzed the data on human occupants tested at Holloman AFB, it was found that this was typical of humans as well as of dummies. The structure and material of the seat determined this response to a great extent; for many of its tests the Bureau approximated production seats with hard seats that slope down toward the front.

In the present dynamic performance testing program the Bureau is using dummies seated in currently produced automobile seats and secured by restraints anchored as in the

continued p. 184

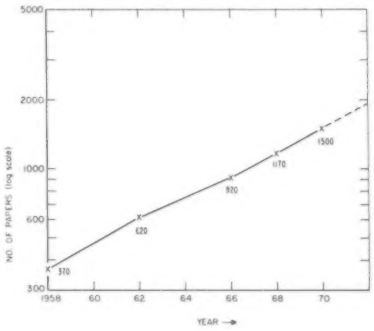
NSRDS NEWS

The NSRDS was established to make critically evaluated data in the physical sciences available to science and technology on a national basis. The NSRDS is administered and coordinated by the NBS Office of Standard Reference Data.

TENTH ANNIVERSARY OF ATOMIC TRANSITION PROBABILITIES DATA CENTER

In June 1970, the Data Center on Atomic Transition Probabilities at the National Bureau of Standards became 10 years old. Because the Center has monitored activities in this field for a decade, the occasion seems an appropriate time to reflect on recent developments and to present some statistical highlights.

When the Center was started, the most complete available bibliography was published in 1958 [1] and contained 370 papers with numerical data on transition probabilities. After an exhaustive literature search in 1960–61, the Center published its first bibliography in June 1962,[2] which contained 620 papers and covered 83 of the 92 elements. No data yet existed for some prominent elements, of which bromine is an example. Since that time the amount of literature has rapidly increased. In 1966 a second bibliography [3] containing about 920 papers was published and was followed in 1968 by a supplement [4] containing another 250 papers. The latest bibliography was published in early 1970 and for the first time is a selected bibliography [5]—many of the early papers that have been judged unreliable were omitted. In June 1970, the Data Center counted about 1500 papers containing numerical data.



Growth of the literature on atomic f-values.

The Center has thus witnessed a strong and steady growth rate in its first 10 years of existence. The added volume of literature is 50 percent larger than the total literature accumulated in the previous 40 years. This growth was stimulated by several factors, primarily the renewed need for atomic parameters resulting from advances in plasmaphysics, space physics, atmospheric physics, astrophysics, and laser technology.

Several new experimental techniques were developed in this decade, most notably the Hanle-effect technique and beam-foil spectroscopy. Research using these two methods now contribute about 25 percent of the new literature. Also, some new and refined theoretical approaches were developed in the 60's, principally the superposition of configurations approach, the nuclear charge expansion method, and the scaled Thomas-Fermi potential method. Important advances were also made in the classical techniques. For example, the vacuum ultraviolet and infrared regions of the spectrum were made accessible by new technologies, and modern data reduction techniques were introduced to greatly improve the quality and quantity of the data. The NBS Data Center group made significant contributions to a number of these developments.

The culmination of the Center's work was the publication in the NSRDS NBS series of 8000 critically evaluated transition probabilities for

New material to be included in the files of the Atomic Transition Probabilities Data Center is reviewed by Center staff members Barbara M. Miles, Wolfgang L. Wiese (center), and Melvin W. Smith.

the first 20 elements of the periodic table,[6, 7] an effort in which the Center has been engaged since 1962. These compilations are being increasingly accepted as standard data. To date about 3000 copies of these NSRDS books have been sold by the Superintendent of Documents or distributed by the Data Center. Furthermore, a study of the Science Citation Index has shown that during the last year the NSRDS books have been quoted more often than any other reference in this field. The Center is now engaged in a new phase of its data compilation effort, the evaluation of f-values on heavier elements.

The staff members of this Data Center, in addition to their compilation and evaluation activities, are actively contributing new material. Some of the data contained in the compilations resulted from calculations undertaken by the members of the Center. Recently detected systematic trends in f-values are also a direct outgrowth of the work of the Center,[8] and have been used to determine almost 2000 additional f-values by interpolation techniques.[9]

BERKELEY PARTICLE DATA CENTER PUBLISHES TWO NSRDS COMPILATIONS

Organized in 1958, the Berkeley Particle Data Center at the Lawrence Radiation Laboratory (University of California) has the mission to compile, reference, average, and summarize data on properties of elementary particles. Its director is Arthur H. Rosenfeld and it is supported by the Atomic Energy Commission through its Lawrence Radiation Laboratory and, since 1968, the Office of Standard Reference Data. Close collaboration with the European Nuclear Center (CERN) is maintained.

The Berkeley Particle Data Center recently published two critically evaluated data compilations. *NSRDS-UCRL-20000 YN, A Compilation of YN Reactions*, January 1970, by Odette Benary, Naomi Barash-Schmidt, LeRoy R. Price, Arthur H. Rosenfeld, and Gideon Alexander, is a compilation of 17 papers that report the cross sections, augular distributions, and polarizations of Ap, Σ^+p, and Σ^-p interactions. Included are indices to the papers, as well as a complete listing of the selected YN data.

NSRDS-UCRL-20030 πN, πN Partial Wave Amplitudes, A Compilation, February 1970, by David J. Herndon, Angela Barbaro-Galtieri, and Arthur H. Rosenfeld; is a collection of the results of ten partial-wave analyses performed on the elastic π^+p scattering from 0 to 2 BeV/c incident momentum. The amplitudes and various parameters deduced from the amplitudes are plotted and tabulated. Necessary definitions are provided.

Copies of both compilations are available from Dr. Arthur Rosenfeld, Director, Berkeley Particle Data Center, Lawrence Radiation Laboratory, University of California, Berkeley, Calif. 94720.

PHOTONUCLEAR DATA INDEX

NBS Special Publication 322, *Photonuclear Index*[10] (75 cents; SD Catalog No. C13.10:322) prepared by the NBS Photonuclear Data Center, is the second in a series of cumulative supplements to NBS Miscellaneous Publication 277[10] (55 cents; SD Catalog No. C13.10:277). SP 322 covers data published in the field of photonuclear reactions during the period January 1, 1965, through January 31, 1970.

The function of this data index is to furnish a means of readily locating experimental data in the field of photonuclear reactions. This index differs from a bibliography in that it supplies quantitative information about the content of a paper. Each entry in the index corresponds to the measurement of a specific photonuclear reaction for a specific nuclide or group of nuclides. An attempt is made to give as complete a description of each measurement as is possible in a single line. The type of measurement is indicated as well as the range of excitation energies covered, the type of detector used and its energy response, and the type of angular distribution data obtained. The object has been to describe sufficiently each measurement so that pertinent references for specific types of data can be located without referring to a large number of irrelevant papers, which might be the case if only the title of the paper or the reaction studied were listed for each entry.

The index uses eight categories to describe a given paper. These are: reference number, nucleus excited, reaction, type of information, excitation energy range, source type and energy range, detector type energy and angular range, and remarks.

PANEL DISCUSSION REPORT ON THERMODYNAMIC PROPERTIES OF FLUIDS

A symposium, The Evaluation of the Thermodynamic Properties of Fluids, was held at Airlie House, Warrenton, Va., November 5–7, 1969. The symposium was sponsored by the Numerical Data Advisory Board of the National Academy of Sciences—National Research Council at the request of the OSRD.

The symposium was planned as a technical meeting for those active or interested in the production and evaluation of data in this field. The primary themes of the symposium were:

1. The estimation of the reliability of experimental, theoretical, and evaluated data, techniques for data evaluation and related problems.

2. Assessment of the needs for evaluated data in science and industry, and discussion of current programs carried out to meet these needs.

These topics were covered in scheduled talks and short informal communications. A detailed discussion of data needs, resources, and programs was carried out by six panels: hydrocarbons; polar fluids (except water); water; atmospheric gases; mixtures and refrigerants. A report of the chairmen's summaries of the deliberations of the six panels has been prepared and a limited number are available from the Office of Standard Reference Data, National Bureau of Standards, Washington, D.C. 20234.

HIGH TEMPERATURE REACTION RATE DATA

The fourth report in a series on the *Critical Evaluation of Rate Data for Homogeneous, Gas Phase Reactions of Interest in High-Temperature Systems* has been issued by D. L. Baulch, D. D. Drysdale, D. G. Horne, and A. C. Lloyd of the School of Chemistry, University of Leeds, England. The report treats the following twelve reactions:

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N + O + M &= NO + M \\
NO + M &= N + O + M \\
N_2 + O_2 &= NO + NO \\
NO + NO &= N_2 + O_2 \\
N_2O + O &= NO + NO \\
NO + NO &= N_2O + O \\
NO_2 + N &= NO + NO \\
NO + NO &= NO_2 + N
\end{aligned}
$$

As in previous reports, the data sheet format is used. The rate data are tabulated for each reaction together with the experimental method used and evaluator's comments. A discussion and a bibliography are provided for each reaction.

This work is part of the High Temperature Rate Data Project supported by the U.K. Office of Scientific and Technical Information, which administers the British Data and Information Program. This Office is the U.K. equivalent to the NBS Office of Standard Reference Data. For further information about the work of the Leeds group or copies of reports, write to Dr. D. L. Baulch, School of Chemistry, The University, Leeds 2, England, U.K.

[1] Kolesnikov, V. N., and Leskov, L. V., Uspekhi Fiz. Nauk **65**, 3 (1958).

[2] Glennon, B. M., and Wiese, W. L., Nat. Bur. Stand. (U.S.), Monogr. 50, 42 pages (1962).

[3] Glennon, B. M., and Wiese, W. L., Nat. Bur. Stand. (U.S.), Misc. Publ. 278, 105 pages (1966).

[4] Glennon, B. M., and Wiese, W. L., Nat. Bur. Stand. (U.S.), Misc. Publ. 278, 46 pages Supplement (1968).

[5] Miles, B. M., and Wiese, W. L., Nat. Bur. Stand. (U.S.), Spec. Publ. 320, 112 pages (1970).

[6] Wiese, W. L., Smith, M. W., and Glennon, B. M., *Atomic Transition Probabilities*, Vol. I (Elements H through Ne), Nat. Bur. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 4, 169 pages (1966)

[7] Wiese, W. L., Smith, M. W., and Miles, B. M., *Atomic Transition Probabilities*, Vol. II (Elements Na through Ca), Nat. Bur. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 22, 310 pages (1969)

[8] Wiese, W. L., and Weiss, A. W., Regularities in Atomic Oscillator Strengths, Phys. Rev. **175**, 50 (1968).

[9] Smith, M. W., and Wiese, W. L. (to be published).

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RESTRAINT *continued*

cars. Sled runs now dynamically simulate 30-mph impacts with immovable barriers, and the speed can be raised to 50 mph if required in the future.

Data are obtained from transducers placed to sense forces in the seatbelts, on the seat, in the dummy's chest, and in its head. Also sensed are the accelleration and velocity of the sled and displacement of the dummy's chest and pelvis, all of which are recorded with a time base on a strip-chart and magnetic tape.

Data on Film

Motion picture photography at high framing rates (up to 1000 frames per second) is being used to record subject displacement and motion. Reference spots are attached to the dummy to mark key points—the ankle, knee, hip joint, shoulder, and head. Successive frames of the film are analyzed to plot movements and reveal those that could be hazardous.

Much of the film of human and dummy tests on the Daisy Decelerator at Holloman Air Force Base is now being analyzed. The films of human tests were made possible by the availability of Airman volunteers for the program; these may be the only films of human performance in automotive seatbelts on the sled for some time to come. NBS, the sole source of these data, is reporting the analyses as they become available by giving papers at conferences, reporting to the sponsor, lending films showing the raw data, and holding informational meetings with industry.

Human Engineering

Studies of current production automobiles show diverse seat and attachment geometry. Also, most restraint systems appear to have been appended to previously designed vehicles, rather than the vehicles designed to give easy access to and ideal performance of the restraint system. A task facing the Bureau is to decide where restraints can be placed and stored for access to the entire range of users. Standards already accepted by industry required that factory-installed seatbelts be capable of meeting system performance requirements when tested in the average location found in production car models. These locations are now known, since the Bureau has surveyed and reported on anchorage locations in all 358 current models of domestic automobiles.

A recent survey on southeastern U.S. highways shows that about 34 percent of the automobile occupants wear lap belts and that only a small percentage of occupants having upper torso restraints use them. While obtaining public acceptance of occupant restraints is not part of the NBS mission, design factors that make restraints difficult, uncomfortable, or inconvenient to use are of legitimate concern and are being studied in the present NBS program.

[1] The other two programs have been reported in: **Braking systems research program**, Nat. Bur. Stand. (U.S.), Tech. News Bull. 53(6) 127–129 (June 1969; SD Catalog No. C13.13:53/6), and **NBS tire research program/motorists to benefit from research for DOT**, Nat. Bur. Stand. (U.S.), Tech. News Bull. 54(1) 12–15 (Jan. 1970; SD Catalog No. C13.13:54/1).

[2] **Auto seatbelt standard set**, Nat. Bur. Stand. (U.S.), Tech. News Bull. 49(2) 30–31 (Feb. 1965), and **Auto seatbelt standards revised**, Nat. Bur. Stand. (U.S.), Tech. News Bull. 51(9) 145 (Sept. 1967).

[3] **Automotive safety research expanded at NBS**, Nat. Bur. Stand. (U.S.), Tech. News Bull. 51(11) 246–248 (Nov. 1967).

FIPS NOTES

In the fall of 1965 the Secretary of Commerce established the NBS Center for Computer Sciences and Technology to carry out the Secretary's responsibilities under the Brooks Bill (Public Law 89–306, passed October 30, 1965). The Center provides leadership and coordination for government efforts in the development of voluntary commercial information processing standards, develops recommendations for Federal information processing standards, performs required research and analysis, and provides scientific and technical support and consultative assistance in the field of computers and information processing to Federal agencies. These Notes will cover information-processing standards activities in the Federal Government, particularly those of the Center.

Harry S. White, Jr., of the NBS Office of Information Processing Standards has recently published an article in *Modern Data*[1] identifying the essential steps in the standardization process. He has found that because standardization is a time-consuming, complex, and costly undertaking, such well-defined procedures need to be established for use by the standardization participants. The procedures should be flexible enough to meet different and various problems, and deviation from the established procedures should be allowed only in extreme or unusual circumstances. Outlined below are twenty basic steps in the standardization process. These steps can be adjusted to meet most standardization situations by revising their sequence or eliminating certain steps when necessary.

1. **Identify requirements.** There must be reasons (economic, public safety, consumer protection, etc.) for initiating a standards effort. The expected benefits need to be identified.

2. **Determine feasibility.** Estimated costs for developing, implementing, and maintaining the standard should be determined. Also, the question of technical feasibility needs to be considered. The state-of-the-art and its relationship to the standard need to be assessed.

3. **Establish priorities.** The urgency of the need for the standard and its place among related standards should be examined. The availability of resources (time, personnel, and other support) needed to accomplish the work should be reviewed and established.

4. **Determine scope of project and program of work.** A well defined scope statement and a detailed program of work with time schedules need to be determined. The coordination and liaison that is necessary with other standardization groups or responsible organizations should be identified.

5. **Initiate project.** A responsible individual or group should review the information obtained in the first four steps and should approve or reject the project. If approved, a

project leader should be selected. Competent individuals who can contribute to the standards development need to be identified and recruited. The standardization procedures to be followed need to be identified and distributed to each participant. Meeting schedules and administrative support should be established.

6. **Identify alternatives.** Efforts to identify the various solutions to solving the technical aspects of the standard need to be identified. Criteria for evaluating these alternatives should also be established.

7. **Evaluate alternatives.** The alternatives identified need to be evaluated against the established criteria. This step of standardization should be well documented.

8. **Prepare proposed standard.** Based upon the evaluation in Step 7, a recommended standard should be written. Guidelines for the format and wording conventions in a standard should be followed.

9. **Prepare proposed implementation plan and applicability of proposed standard.** The areas of applicability together with a recmended implementation schedule should be identified. Techniques that can be employed to facilitate the effective and timely implementation of the standard should be prepared. Exception procedures should be considered and defined.

10. **Coordinate proposed standard.** The proposed standard needs to be forwarded to those affected parties and organizations for review and comment.

11. **Resolve differences.** All negative responses to a proposed standard should be addressed and answered. Attempts should be made to resolve differences either by making adjustments to the proposed standard or by persuading the non-concurring agency to reconsider based upon additional facts or reasoning. If major changes are made, the proposed standard should be re-coordinated.

12. **Determine consensus.** A consensus is more than a majority and may be less than unanimity. Generally, two-thirds in support of a proposed standard can be defined as a consensus.

13. **Revise proposed standard.** As a result of the coordination and further negotiations, changes to the original proposed standard are usually necessary.

14. **Identify basis for exceptions.** The applicability and implementation sections of the proposed standard may have to be modified as a result of coordination. Exceptions to the use of the standard should be reviewed and clearly explained.

15. **Assess implementation impact.** The cost benefits of implementing the standard should be reexamined. This should include a comparison of the cost of conversion (if any) to the expected near and long term benefits to be derived from the use of the standard.

16. **Forward revised proposed standard for approval.** The proposed standard as revised should be forwarded with all supporting documentation to the approving authority. Minority positions should be included.

17. **Approve standard.** The approving authority should review the proposed standard and supporting documentation. It may be approved, modified, or rejected.

18. **Promulgate the standard.** If approved, the standard should be published and made available on a timely basis to all concerned.

19. **Execute implementation plan.** Responsible organizations should take necessary actions to insure that the standard is implemented according to the approved implementation plan.

20. **Maintain the standard.** Each standard should have a sponsor or agent that is held responsible for the standards maintenance. The maintenance requirements will vary depending upon the nature of the standard. In some cases, detailed maintenance procedures need to be determined in the early phases of the development of the standard.

These steps are common to most standardization efforts, nationally and internationally. Voluntary standardization activities generally do not address the aspect of the standards implementation (planning and execution). This is done by those organizations that voluntarily adopt the standard.

FIPS PUBS AVAILABLE FROM CLEARINGHOUSE

Arrangements have been completed to make Federal Information Processing Standards Publications (FIPS PUBS) available through the NBS Clearinghouse for Federal Scientific and Technical Information (CFSTI). This will promote wider and more effective use of these standards by the scientific community, industry, and commerce. In addition to the availability of FIPS PUBS from the Clearinghouse, they will continue to be stocked and sold by the Superintendent of Documents, U.S. Government Printing Office.

FIPS PUBS will also be reproduced in microfiche form by the Clearinghouse and will cost 65 cents per document. Paper copy documents from the Clearinghouse are the same price as charged by the Superintendent of Documents. Also, certain standards will be available from the Clearinghouse in machine readable form (punched cards and magnetic tapes).

In the future, all FIPS PUBS will

be announced in the U.S. GOVERNMENT RESEARCH & DEVELOPMENT REPORTS (USGRDR) which is a semi-monthly abstract journal. Annual subscription $30 ($37.50 foreign).[2]

Of particular interests to ADP users and information specialists are Clearinghouse Announcements in Science and Technology (CAST). These announcements are extracts from the USGRDR for particular subject categories. Of the 35 categories (numbered from 51 to 85), two pertain to computers and information processing: Category 62, Computers, Control Theory, and Information Theory, contains information relating to computer hardware and software, control systems and control theory, information processing standards, and information theory; and Category 70, Managerial and Information Sciences, contains information on administration and management, information sciences, inventory control, management information systems, personnel management, labor relations, manpower studies, reference materials and library aids, and research program administration and transfer of technology.

The CAST announcements are published semi-monthly, and may be obtained on a subscription basis only. The annual subscription for one category is $5 ($6.25 foreign).[2]

ACTIONS AFFECTING AMERICAN NATIONAL STANDARDS

The American National Standards Institute has initiated a new biweekly publication entitled STANDARDS ACTION to announce new or revised American National Standards for the purpose of soliciting the views of interested parties. It also solicits comments on proposed actions to reaffirm or withdraw particular American National Standards.

The title and description of each standard on which action is proposed are listed along with the time limit for comments. Also, the name and address of the organization from which a copy of the proposed new or revised standard may be obtained is given. If any cost is involved, the amount is cited.

STANDARDS ACTION is distributed on a cost free basis by the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

TRANSPORTATION DATA STANDARDS

In recognizing the need to facilitate and improve the management and systems support for transportation information, The Transportation Data Coordinating Committee (TDCC) has been organized to develop and install standardized information and systems for data exchange. TDCC is a nonprofit industrial organization located at 1101 17th Street, N.W., Washington, D.C. 20036. Edward A. Guilbert is the TDCC President. Thomas H. Desnoyers is the TDCC Director of Codes and Standards. The TDCC program and objectives are supported by the National Industrial Traffic League, Transportation Association of America, Association of American Railroads, and the American Trucking Associations. It has received endorsement from the Department of Transportation, Interstate Commerce Commission, Federal Maritime Commission, and the Civil Aeronautics Board. Coordination with the Federal data standardization program has been effected through the Bureau of the Budget and NBS. Mr. Desnoyers is representing the transportation interests in the standardization work of the American National Standards Institute.

At the present time, the Transportation Data Coordinating Committee has organized five task-forces in the codes area. The five task forces and the areas that they will operate in include:

1. **Commodity Related Codes Task Force.** Commodity codes, packaging codes, volume and volume measurement standards, density standards, value standards.
2. **Carrier Related Codes Task Force.** Carrier name codes, carrier equipment and capacity standards and codes, carrier equipment dimensional characteristics codes, vehicle identification numbering, special intermodal container or vehicle codes.
3. **Geographic Related Codes Task Force.** Consignor and consignee (patron) code, geographic region codes—country, state, province, and specialized regions, specific point location codes.
4. **Tariff Related Codes and Instruction Codes Task Force.** Transportation mode, route codes, junction codes, tariff and document numbering, tariff rules and regulations codes, monetary unit for expression transportation charges.
5. **Code Theory and Technical Development Task Force.** Technical code designs, numbering systems and code characteristics, check digits, alphabetic abbreviation rules, code implementation data coordination.

Other task forces have been formed to:

1. Review transportation data needs and develop codes and standard programs.
2. Recommend code projects based on the transportation needs of shippers, carriers, and inventors.
3. Inform users of individual code programs by maintaining a close liaison with all code programs.

Representatives from shippers, carriers, and other interested groups comprise the membership on the task forces.

[1] White, Harry S., Jr., Data Management and Standardization, Modern Data, 2, No. 5, 52–56 (May 1969). Available from NBS Clearinghouse, U.S. Department of Commerce, Springfield, Va. 22151 for $3. Order by Accession Number PB179213.

[2] To order, make check or money order payable to the NBS Clearinghouse. Mail to CFSTI (152.12), U.S. Department of Commerce, Springfield, Va. 22151.

STANDARDS AND CALIBRATION

IMPROVED ACCURACY IN THOMAS-TYPE ONE-OHM STANDARD RESISTOR CALIBRATION

On July 1, 1970, the Bureau began reporting the calibration value of double-walled Thomas-type resistors to eight decimal places. The total uncertainty of a calibration is 0.08 parts per million based on a three standard deviation limit for random errors of 0.048 and an allowance of 0.027 parts per million for systematic errors due to possible uncorrected effects of temperature and pressure. This represents a ten-fold improvement over previous capability. There will be no increase in cost for the improved service above the present fee of $90 per resistor, which includes a recent increase in all fees.[1]

The Legal Ohm in the United States is maintained with a group of these very stable units, which were constructed at the Bureau many years ago under the direction of Dr. J. L. Thomas. Inasmuch as all other resistance measurements at NBS, from 10^{-4} to 10^{14} ohms, are derived from this one-ohm base, improvements at this level have a great deal of significance.

An entirely new measurement system, devised early in 1969, made the improved accuracy possible. Analysis of many hundreds of measurements made with the new system has indicated that the resistance value of Thomas-type standards may now be reported to 0.01 ppm instead of the former 0.1 ppm.

In the new measuring technique, the potential drop across each resistor under calibration is compared indirectly (via a stable dummy resistor) with the mean of the voltage drop across each of the resistors in the reference group, while all are connected in series and totally immersed in an oil bath maintained at 25.000 ± 0.003 °C. A dc current comparator is used for making the comparisons while all resistors are carrying a continuous 0.1-ampere test current.

The new measurement system has the following advantages: High inherent stability of the dc primary and secondary current ratios (small changes in these ratios are known accurately); elimination of tedious and time consuming lead balancing, which was previously necessary; resistors are now compared directly with the National Reference Group of standards, rather than through a secondary or "working" group of standards as was done previously; lower test current (0.1 amp. dissipating 0.01 watt) in each resistor under test; improved temperature uniformity and control resulting from all resistors being completely immersed in a covered and thermally insulated oil bath, which is allowed to come to thermal equilibrium before the calibration; and, all switching is externally controlled.

As resistors of the double-wall type are affected slightly by the pressure of the surrounding medium, pressure information will be reported along with the normally supplied calibration data.

STANDARD FREQUENCY AND TIME BROADCASTS

High-frequency radio stations WWV (Fort Collins, Colo.) and and WWVH (Maui, Hawaii) broadcast time signals on the Coordinated Universal Time (UTC) system as coordinated by the Bureau International de l'Heure (BIH), Paris, France. The NBS time scale, UTC (NBS) and the U.S. Naval Observatory time scale, UTC(USNO) are jointly coordinated to within ± 5 microseconds. The UTC pulses occur at intervals that are longer than one coordinate second by 300 parts in 10^{10} during 1970, due to an offset in carrier frequency coordinated by BIH. To maintain the UTC scales in close agreement with the astronomers' time, UT2, phase adjustments are made at 0000 hours Greenwich Mean Time (GMT) on the first day of a month as announced by BIH. *There will be no adjustment made on September 1, 1970.*

The low-frequency radio station WWVB (Fort Collins, Colo.) broadcasts seconds pulses without offset to make available to users the standard of frequency so that absolute frequency comparisons may be made directly, following the Stepped Atomic Time (SAT) system. Step time adjustments of 200 ms are made at 0000 hours GMT on the first day of a month when necessary. BIH announces when such adjustments should be made in the scale to maintain the seconds pulses within about 100 ms of UT2. *There will be an adjustment made on September 1, 1970. The seconds pulses emitted from WWVB will be retarded 200 ms.*

NBS obtains daily UT2 information from forecasts of extrapolated UT2 clock readings provided by the U.S. Naval Observatory with whom NBS maintains close cooperation.

[1] For a complete list of NBS calibration services see, Calibration and Test Services of the National Bureau of Standards, Nat. Bur. Stand. (U.S.), Spec. Publ. 250 (1968 ed., $1.75; SD Catalog No. C13.10:250).

CONFERENCE & PUBLICATION *Briefs*

LECTURES ON MODULAR FORMS

Lectures on Modular Forms, edited by Joseph Lehner, NBS Applied Mathematics Series 61 (70 cents, SD Catalog No. C13.32:61), is an exposition of the theory of modular forms that starts with the classical material and leads gradually to modern developments and applications. Groups of integral matrices (with their fundamental applications to crystallography), conformal mapping, ergodic flows, symmetries on manifolds, and number theory are among the many disciplines to which modular form theory has been applied.

Scheduled NBS-Sponsored Conferences

Each year NBS sponsors a number of conferences covering a broad range of topics in science and technology. The conferences listed below are either sponsored or cosponsored by NBS and will be held at the Bureau's Gaithersburg, Md., facility unless otherwise indicated. These conferences are open to all interested persons unless specifically noted. If no other address is given, inquiries should be sent to the person indicated below in care of Special Activities Section, Room A600, Administration Building, National Bureau of Standards, Washington, D.C. 20234.

Space Simulation Conference. Sept. 14–16. Cosponsors: American Institute of Aeronautics and Astronautics; Institute of Environmental Sciences; American Society for Testing and Materials. Contact: J. C. Richmond (NBS Heat Division).

National Metric Study Conferences. Sept. 21–25, Oct. 5–6, Oct. 12–13, Oct. 14–16, Oct. 27–29, and Nov. 16–20. Contact: J. Odom (NBS Office of Invention and Innovation). To be held at Department of Commerce Auditorium, Washington, D.C.

25th Calorimetry Conference. Oct. 19–22. Contact: E. Domalski (NBS Physical Chemistry Division).

4th Materials Research Symposium—Pyrolysis, Oxidation, and Burning. Oct. 26–30. Contact: L. A. Wall (NBS Polymers Division).

The Science of Ceramic Machining and Surface Finishing. Nov. 2–4. Cosponsors: Office of Naval Research; American Ceramic Society. Contact: S. J. Schneider (NBS Inorganic Materials Division).

Symposium on the Application of Computers to Environmental Engineering Design. Nov. 30–Dec. 2. Cosponsor: American Society of Heating, Refrigerating and Air Conditioning Engineers. Contact: R. Achenbach (NBS Building Research Division).

Flow—Its Measurement and Control in Science and Industry. May 10–14, 1971. Cosponsors: American Institute of Physics; American Society of Mechanical Engineers; Instrument Society of America. Contact: V. J. Giardina, Instrument Society of America, 400 Stanwix Street, Pittsburgh, Pa. 15222. To be held in Pittsburgh, Pa.

Fifth Symposium on Temperature Measurement and Control in Science and Industry. June 21–24, 1971. Cosponsors: American Institute of Physics; Instrument Society of America. Contact: H. H. Plumb (NBS Heat Division).

PUBLICATIONS of the National Bureau of Standards*

PERIODICALS

Technical News Bulletin, Annual Subscription: Domestic, $3; foreign, $4. Single copy price 30 cents. Available on a 1-, 2-, or 3-year subscription basis. SD Catalog No. C13.13:54.

Journal of Research of the National Bureau of Standards

Section A. Physics and Chemistry. Issued six times a year. Annual subscription: Domestic, $9.50; foreign, $11.75. Single copy price varies. SD Catalog No. C13.22/sec.A:74.

Section B. Mathematical Sciences. Issued quarterly. Annual subscription: Domestic, $5; foreign, $6.25. Single copy, $1.25. SD Catalog No. C13.22/sec.B:74.

Section C. Engineering and Instrumentation. Issued quarterly. Annual subscription: Domestic $5; foreign $6.25. Single copy, $1.25. SD Catalog No. C13.22/sec.C:74.

CURRENT ISSUE OF THE JOURNAL OF RESEARCH

J. Res. Nat. Bur. Stand. (*U.S.*), **74B** (*Math. Sci.*), No. 3 (July–Sept. 1970), SD Catalog No. C13.22/sec.B:74/3.

Atchison, T. A., Selecting nonlinear transformations for the evaluation of improper integrals.

Cezairliyan, A., Derivatives of the Grüneisen and Einstein functions.

Holt, R. D., Expansions with coefficient algorithms for time domain responses of skin effect lossy coaxial cables.

Knopp, M. I., and Smart, J. R., Hecke basis theorems for groups of genus O.

Mandel, J., The distribution of eigenvalues of covariance matrices of residuals in analysis of variance.

Rhodes, D. R., On the spheroidal functions.

Stegun, I. A., and Zucker, R., Automatic computing methods for special functions.

OTHER NBS PUBLICATIONS

American National Standard, Radiological safety in the design and operation of particle accelerators, Nat. Bur. Stand. (U.S.), Handb. 107, 22 pages (June 1970) 30 cents, SD Catalog No. C13.11:107.

Benson, S. W., O'Neal, H. E., Kinetic data on gas phase unimolecular reactions, Nat. Bur. Stand. (U.S.), Nat. Stand. Ref. Data Ser. 21, 645 pages (Feb. 1970) $7, SD Catalog No. C13.48:21.

Bullis, W. M., ed., Methods of measurement for semiconductor materials, process control, and devices, Quarterly Report October 1 to December 31, 1969 Nat. Bur. Stand. (U.S.), Tech. Note 527, 60 pages (May 1970) 60 cents, SD Catalog No. C13.46:527.

Diamond, J. J., ed., Bibliography on the

high temperature chemistry and physics of materials, January, February, March, 1970, Nat. Bur. Stand. (U.S.), Spec. Publ. 315-5, 82 pages (Apr. 1970) 75 cents, SD Catalog No. C13.10:315-5.

Eisele, J. W., Types and sizes of forms for one-way concrete joist construction, Nat. Bur. Stand. (U.S.), Prod. Stand. 16-69, 16 pages (June 1970), 10 cents, SD Catalog No. C13.20/2:16-69.

Faison, T. K., Jr., Davis, J. C., Achenbach, P. R., Performance of louvered devices as air mixers, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 27, 22 pages (Mar. 1970) 30 cents, SD Catalog No. C13.29/2:27.

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Hellwig, H., Hydrogen spin exchange frequency shifts, Nat. Bur. Stand. (U.S.), Tech. Note 387, 13 pages (March 1970), 30 cents, SD Catalog No. C13.46:387.

Jones, M. C., Far infrared absorption in liquefied gases, Nat. Bur. Stand. (U.S.), Tech. Note 390, 39 pages (April 1970), 50 cents, SD Catalog No. C13.46:390.

Jones, R. N., Huntley, L. E., A precision, high frequency calibration facility for coaxial capacitance standards, Nat. Bur. Stand. (U.S.), Tech. Note 386, 27 pages (March 1970), 35 cents, SD Catalog No. C13.46:386.

Lutz, G. J., ed., Determination of the light elements in metals: A bibliography of activation analysis papers, Nat. Bur. Stand. (U.S.), Tech. Note 524, 66 pages (May 1970), 75 cents, SD Catalog No. C13.46:524.

Lutz, G. J., Boreni, R. J., Maddock, R. S., Meinke, W. W., eds., Activation Analysis: A bibliography, Nat. Bur. Stand. (U.S.), Tech. Note 467, Part 1, Addendum 1, 176 pages (Dec. 1969) and Part 2, Appendices, Revision 1, Nat. Bur. Stand. (U.S.), Tech. Note 467, 264 pages (Dec. 1969), $8.50 per set of 3 volumes, sold in sets only. Part 1 of September 1968 accompanies these sets, SD Catalog No. C13.46:467.

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Penner, S., Beam handling techniques for electron linear accelerators, Nat. Bur. Stand. (U.S.), Tech. Note 522, 21 pages (Apr. 1970), 30 cents, SD Catalog No. C13.46:522.

Photonuclear data index, January 1965 through January 1970. Nat. Bur. Stand. (U.S.), Spec. Publ. 322, 86 pages (May 1970), 75 cents, SD Catalog No. C13.10:322 (Supersedes Supplement 1 to Misc. Publ. 277).

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Stevens, M. E., Automatic Indexing: A state-of-the-art report, Nat. Bur. Stand. (U.S.), Monogr. 91, 290 pages (Mar. 1965), $2.25, SD Catalog No. C13.44:91. (Reissued with additions and corrections February 1970.)

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This column lists all publications by the NBS staff, as soon after issuance as practical. For completeness, earlier references not previously reported may be included from time to time.

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